Handbook of Best Practices: *Room Air Conditioner Installation for the Lowest Carbon Footprint*

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Preface

This handbook focuses on equipment for room cooling only. A subsequent handbook will consider reversible heat pumps.

The Importance of Energy Efficiency and Climate-Friendly Refrigerants

We recommend selecting only high-efficiency cooling equipment proven to be climate-safe across its life cycle, including manufacture, installation, use, service, and recycling at the end of product life. This equipment necessarily uses refrigerants that are safe for the stratospheric ozone layer and has lower global warming potential (GWP). Use the life cycle climate performance (LCCP) metric to deliver the lowest carbon footprint at affordable life cycle ownership costs considering self-interest and future generations. Be mindful of atmospheric fate.

Refrigerants of Choice for Room Air Conditioners (RACs)

At the time of this publication (spring 2025), in regions with regulations that insist on lower-GWP, high energy efficiency, and no trifluoroacetic acid (TFA) or per- and polyfluoroalkyl substance (PFAS) atmospheric degradation products, the market choice of refrigerant is overwhelmingly R-32, with R-290 sold in India and a few other markets. Several refrigerant blends have been proposed, but none so far have penetrated markets, and most blends have TFA or PFAS atmospheric degradation byproducts.

The most efficient room air conditioners (RACs) use R-32 or R-290 refrigerants with inverter designs that automatically adjust compressor motor speed to deliver the lowest carbon footprint at partial and full load. Keep in mind that in hot and humid climates with long cooling seasons that are getting longer and hotter from climate change, any higher cost of the most efficient RACs is rapidly paid back from lower electricity costs. Also keep in mind that the cost savings from higher energy efficiency are invested by consumers locally in education, health, nutrition, and other goods and services essential to quality of life and community prosperity.

Avoid RACs with obsolete R-22 and R-410A refrigerants scheduled for phase out and phase down, respectively, under the Montreal Protocol. These refrigerants will become expensive or unavailable for service during the expected life of a new RAC. Consider that the 2024 EU F-gas regulation prohibits the export of cooling equipment not qualified for sale in Europe, including R-22 and R-410A. Additionally, the United States Environmental Protection Agency (US EPA) has signalled that regulations implementing the Kigali Amendment to the Montreal Protocol will also insist that exports meet domestic standards for allowable refrigerant GWP.

Safety Considerations

This handbook complements the installation manuals and training provided by the manufacturer and/or independent training enterprises. Be sure to comply with local building codes and standards that may require additional design features and installation and service procedures for safety. Examples of safety measures include wearing personal protective equipment (PPE) during equipment installation and maintenance and using stronger mounting brackets and cables preventing outdoor units from falling in locations with earthquakes or strong winds.

Comprehensive Energy Efficiency Lowers RAC Ownership Cost

Ultimately, with all costs and benefits considered, the most affordable RAC is the one that is the most energy efficient. A combination of best practices delivers comprehensive energy efficiency, including:

- Designing and building energy-efficient structures.
- Cooling buildings only while occupied.
- Selecting equipment based on lowest life cycle carbon footprint.
- Siting and installing indoor units (IDUs) to provide unobstructed airflow to occupants.
- Siting and installing outdoor units (ODUs) so they are shaded from the summer sun and near the IDU, using short refrigerant pipes and a small refrigerant charge.
- Providing enough space between the outdoor RAC unit and the wall and between other outdoor RAC units for maximum airflow and ingestion of only ambient temperature or cooler air.
- Scheduling and performing frequent service cleaning of IDU air filters, removing debris from the ODU heat exchangers, and removing anything that obstructs airflow.

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1. Introduction

This handbook explains exactly how to appropriately install high-efficiency room air conditioners (RACs) for the highest energy efficiency and lowest carbon footprint over the products' lifetime.

Figure 1 illustrates indicative examples of poor installations of RAC indoor units (IDUs) and outdoor units (ODUs).

(a) Insufficient inlet clearance (b) Obstacle at outlet flow

(c) Concealed ODU (d) Reversed flow and no wall clearance (e) Stacked ODUs

Figure 1: Poor installation examples.

Figure 1(a) shows minimal clearance between the top of the IDU and the ceiling, which results in limited airflow to the inlet on the IDU's top side. Figure 1(b) shows two separate IDU units installed in the same room. Similar to the issue in Figure 1(a), both IDUs are installed too close to the ceiling, which limits the inlet airflow. In addition, the IDUs are too close to each other, with both units competing for air intake. Furthermore, office furniture is located just below the IDUs, which obstructs the outlet airflow. Complicating matters more, the two IDUs send cool air to the same area, resulting in uneven space cooling throughout the room, which causes occupants to interfere with their regular operation and waste more energy. Finally, IDU 2 requires much longer piping to connect to its ODU in comparison to IDU 1, which causes more refrigerant-side pressure drop that deteriorates its energy efficiency.

Figure 1(c) shows four outdoor units (ODUs) installed in the concealed space of the building, causing an obstructed and recirculated warm air supply, thus deteriorating the energy efficiency. Figure 1(d) shows the reversed airflow case without any clearance against the wall. Figure 1(e) shows multiple ODUs stacked vertically. Warm air from the lower unit flows upward, resulting in hotter air supplied to the upper ODUs, which deteriorates energy efficiency.

Figure 2 illustrates good installation examples of both IDUs installed with a proper spacing of 300 millimetres (mm) to the ceiling, without any objects obstructing the outlet airflow. Moreover, the two IDUs are installed in parallel to enable uniform space cooling without interfering with each other. Two matching ODUs are installed just behind their respective IDUs, which reduces the piping length, resulting in higher energy efficiency at a lower refrigerant charge. The left side of Figure 2(b) shows that both ODUs were installed with proper spacing of 160 mm to the wall without any objects obstructing the outlet airflow.

(a) IDUs with good spacing (b) ODUs with good spacing

Figure 2: Good installation examples.

2. Selecting an Energy Efficient Location for Indoor and Outdoor Air Conditioning Units

Figure 3 illustrates the airflow around the IDU and ODU. The following information describes best practices for siting indoor and outdoor units.

2.1. Indoor Unit (IDU)

To ensure optimal product performance and longevity, consider the following factors when selecting the location of an IDU:

- **Follow installation drawings**: Strictly adhere to the minimum clearance and placement requirements outlined in the unit's installation manual. Increase the clearance to be greater than the minimum when possible.
- **Ensure unobstructed airflow**: Both the air inlet and outlet must have clear paths for optimal air circulation. Airflow should not be obstructed by curtains or furniture. IDUs should be located at the minimum recommended distance from the wall and ceiling. (For example, 300 mm and 500 mm or more distances are recommended for the side and ceiling spacing, respectively, as shown in Figure 4.)
- **Maintain even air distribution**: Choose a location that allows efficient, excellent air circulation throughout the room.
- **Install at recommended height**: For optimal airflow and user comfort, install the unit at the recommended height of approximately 1.8 m. While the conditioned cool air sinks, the warm room air rises due to the density difference.
- **Minimize distance from IDU to the ODU**: To minimize the refrigerant charge and enhance energy efficiency, minimizing the pipe length between the IDU and ODU is essential. Therefore, select the installation wall where the piping length can be minimal.
- **Avoid direct sunlight**: To prevent overheating and potential malfunction, do not place the ODU in direct sunlight.
- **Avoid heat sources**: Keep the IDU away from sources of heat or steam, such as stoves, radiators, and fireplaces.
- **Prevent oil mist**: Install the IDU away from areas with a machine or cooking oil vapor or relocate any source of oil mist, which can contaminate the IDU’s electronics and heat exchanger.
- **Maintain clearance for service**: Avoid placing furniture or other objects around the IDU that could interfere with proper IDU service, including filter and cooling fin cleaning. Also, confirm that proper condensate drainage occurs through the condensate hose.
- **Minimize electronic interference**: Maintain a minimum distance of 1 m from electronic equipment such as fluorescent lights, internet routers, microwave ovens, radios, and televisions to prevent interference, including with RAC remote controls.
- **Avoid laundry locations**: Avoid placing the unit in a room with laundry equipment. The humidity and heat generated by clothes washers and dryers can harm cooing performance and increase electricity use.

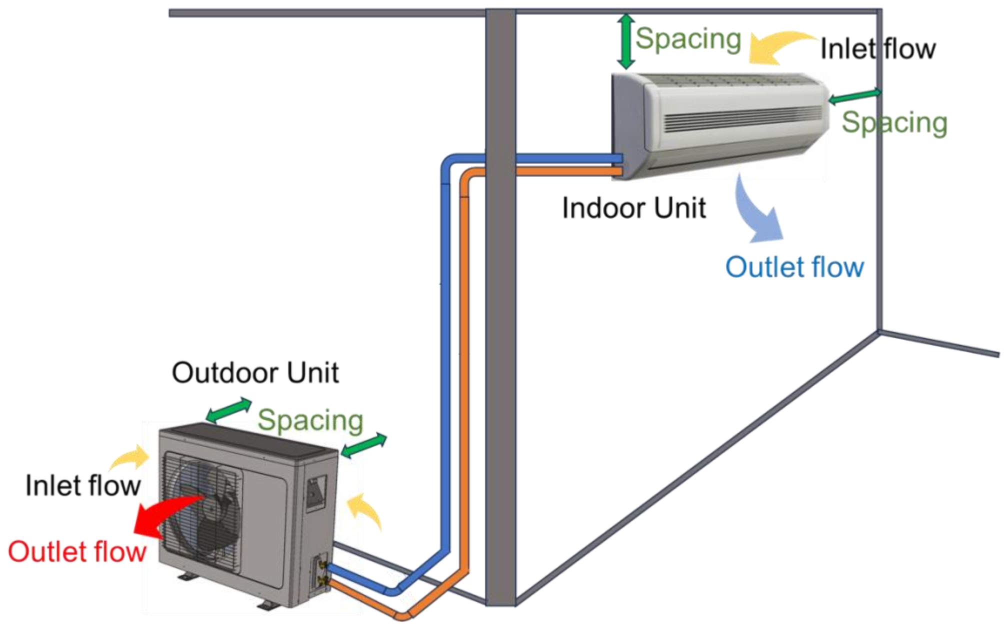

Figure 3: Air flows around the IDU and ODU of the RAC system.

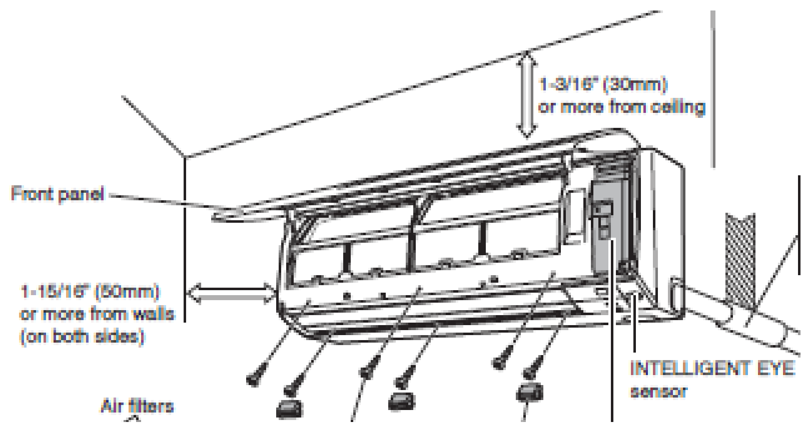

Figure 4: IDU installation guide example.

(Reference: Installation manual)

2.2. Outdoor Unit (ODU)

To ensure the RAC unit operates efficiently, with minimal noise and vibrations, and remains protected from damage, be sure to consider the following factors when selecting an outdoor air conditioning unit (ODU) placement.

- **Optimize Performance:**
  - **Heat rejection**: Locate the ODU away from heat sources such as other RAC ODUs, clothes dryers, or direct sunlight, especially during peak cooling hours.

- **Good ventilation**: Locate the ODU at a location with unobstructed air movement and ensure that ventilation openings are not blocked by walls, landscaping, or other obstructions. Maintain unrestricted airflow around the unit. Avoid placing the ODU in corners, under overhangs, in alcoves, or in any location that might restrict air intake or exhaust. Keep fences and plants well away from the ODU. Maintain adequate space around the ODU to allow optimal airflow and heat rejection, ultimately improving efficiency.
- **Clearance**: Follow the specific RAC unit's installation manual for recommended minimum and optimum clearance distances. For example, 100 to 300 mm or more distances are recommended for the side and back of the ODU, as shown in Figure 5.)
- **Refrigerant piping lines**: Maximize efficiency using the shortest possible refrigerant lines with minimal bends.

- **Protect the Unit:**
  - **Unpack the ODU**: Do not allow the ODU to tilt during unpacking because this will place mechanical stress on the compressor’s connecting pipes. Cut open the box at floor level and gently pull the box upward.
  - **Prevent physical damage**: Mount the ODU away from areas with high foot traffic or potential impact from landscaping equipment and bicycles.
  - **Shield the ODU from debris**: Protect the heat exchanger from becoming clogged by debris such as airborne paper, leaves, or grass clippings, or with dust and mud.
  - **Consider normal and extreme weather events**: Consider fabricating a snow and rain shield on the sides to shield the ODU from the rain pouring off the building and to prevent snow accumulation on and around the ODU.
  - **Piping protection**: Ensure the refrigerant piping is well insulated and protected from physical damage.

- **Maintain Structural Integrity:**
  - **Mounting**: Use robust mounting brackets and appropriate fasteners (screws or bolts) to secure the unit to a strong structure, considering weight, wind load, and earthquake risk (if applicable).

- **Minimize Nuisance:**
  - **Sound and vibration**: Avoid clustering or stacking units. Ensure the unit is level. Locate the ODU where noise and vibration won't bother you or your neighbours.
  - **Head protection**: Ensure the unit is placed clear of walkways to prevent even the tallest pedestrians from bumping their heads on the ODU.

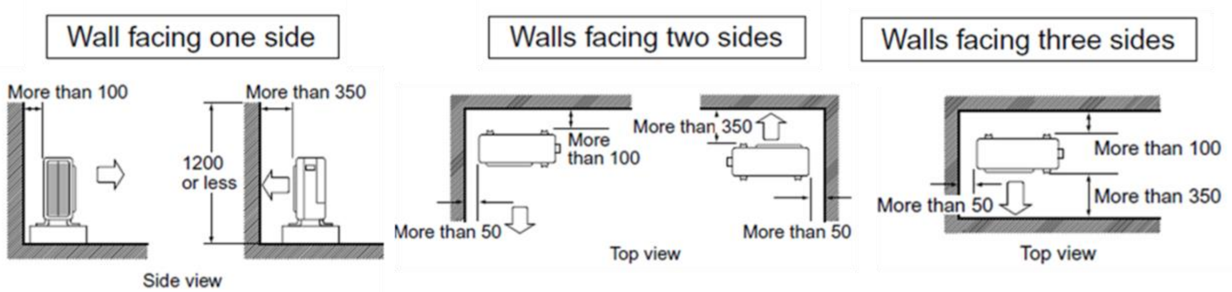

Figure 5: ODU installation guide examples with metric measures (mm).

(Reference: Installation manual)

3. Refrigerant Piping

This section contains best practices for …

- **Piping material selection**: Use type ACR copper piping for air conditioning applications as defined in the Copper Development Association's *Copper Tube Handbook* (or as specified in the installation guide for the specific model RAC).
- **Piping diameter and thickness**: Use only pipe diameter and thickness specified in the installation manual for the specific model.
- **Piping length and height**: While the shortest piping length and height is preferred, acceptable pipe length is from 1.5 meters (m) minimum to 15 m maximum, and acceptable height is 12 m or as specified in the manual.
- **Piping handling**: Always protect the pipe's open end from dust and moisture contamination.
- **Piping bending**: Refrigerant piping lines without joints or couplers are preferred. Use long-radius tube benders for smooth, long-radius bends without marking, scraping, or flattening. Generally, the minimum bending radius should not be less than two times the outer diameter of the pipe. Long-radius 90-degree elbows decrease the pressure drop by 15 to 20 percent over standard and short-radius elbows.
- **Pipe joining**: There are multiple methods for pipe joining, including brazing, soldering, flare joints, quick-connects, and threaded and compression fittings. Brazing is the recommended method because it is the most leak-tight and reliable. When using the threaded fitting for the ODU's service valve, use the torque specified in the installation manual. Note that the use of quick-connect fittings is not recommended.

4. Refrigerant Leakage Checking

There are three common ways to check a system for refrigerant leakage: pressure test with soap solution, electronic leak detector test, and system pressure change test. Leakage can be tested and detected by using the following steps: Start with the bubble test to find a relatively large leak. Then move to the electronic leak detector test to find a relatively minor leak. Lastly, run the system pressure change test to confirm the system is leak-tight or find a small leak.

1. Bubble test:
   - Charge the system with dry nitrogen up to the system design pressure.
   - Prepare or purchase leak-detection soap solution with a propensity of sustained bubbles.
   - Apply soap solution to all sides of all joints and observe for bubbles. Soap bubbles indicate leakage location.
2. Electronic leak detector test:
   - Select an electronic leak detector designed to find small leaks of refrigerant in use.
   - Add about 50–100 g of refrigerant specified for the cooling equipment to the empty system. If available, use recovered refrigerant.
   - Charge the system with nitrogen to its design pressure.
   - If necessary, shield the equipment from the wind.
   - Move the probe of the electronic leak detector slowly around all joints.
   - Locate the leak point via the device's leak detection sound and/or flashing lights.
   - Note that electronic leak detection is the most reliable method to find a small refrigerant leak.
3. System pressure change test:
   - Charge the system with nitrogen up to the system design pressure or even higher if indicated in the equipment installation instructions.
   - Measure the system pressure and ambient temperature over a period of at least 12 hours (usually overnight). Note that pressure should remain unchanged if there are no leaks unless the ambient temperature increases. Leakage is indicated when the system pressure decreases while the ambient temperature is unchanged or increases.
   - Note that this method is a useful way to find a relatively small leak. The system is leak-tight if the system pressure increases, and ambient temperature increases according to the gas law equation ($P1/T1=P2/T2$).
4. Fix the leakage, retest, and confirm the system is leak-tight.
   - Once the leakage is found, fix the leakage.
   - Repeat the system leakage testing described above until no leaks are found.

5. Evacuation and Vacuum Test

Once the system is confirmed to be leak-tight with the pressure test in Step 4 (Refrigerant Leakage Checking), start the evacuation procedure and vacuum test as follows:

- Connect two service valves of the ODU to the pressure gauge manifold, as shown in Figure 6.

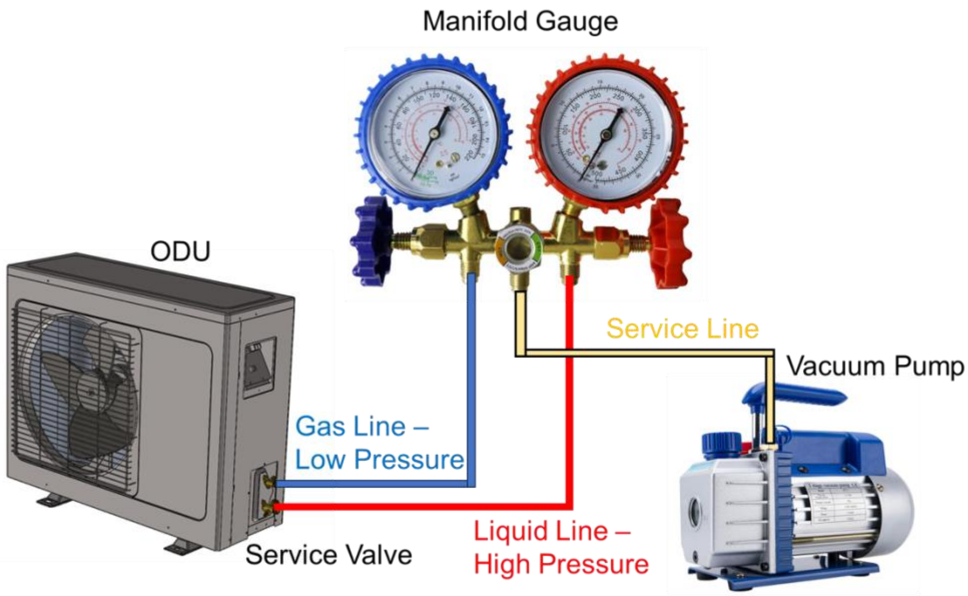

Figure 6: ODU connected with vacuum pump through manifold gauge.

- Connect the service port of the manifold to the vacuum pump.
- For the evacuation procedure, open both manifold valves.
- After running the vacuum pump for at least one hour, check the vacuum pressure. If the vacuum pressure reaches 500 microns, then the evacuation is complete. If the vacuum pressure does not reach 500 microns, the system is not leak-tight, and step 4 (Refrigerant Leakage Checking) will need to be repeated.
- After shutting off the vacuum pump hand valves, turn off power to the vacuum pump.
- After waiting 15 minutes or longer, check the system pressure to see whether the vacuum is maintained. The evacuation and test should be repeated if the system pressure rises above 500 microns. If the system pressure rises again in the second round, leakage needs to be fixed, and Step 4 (Refrigerant Leakage Checking) and Step 5 (Evacuation and Vacuum Test) must be repeated until no leaks are indicated.

6. Electric Wiring

Electrical wiring work must comply with relevant local and national regulations and with the RAC product's installation manual. A RAC draws a large electric current, especially fixed speed compressors during start up or in extremely hot weather. Thus, a highly recommended best practice is to connect the RAC to a dedicated power supply circuit only on a separate circuit breaker. Using a circuit with insufficient power capacity and relying on low cost and low quality craftsmanship can cause electrical shocks, short circuits, and electrical fires. Small gauge wire with higher electrical resistance will waste electricity and increase the risk of fire.

To correctly design, install, and maintain the RAC's electrical systems, ensure that the power supply system complies with the RAC's electrical specifications, which can be found on the ODU's label or in the installation manual. Table 1 is an example of specifications of standard wiring components. Several more recommendations follow:

- Oversized wire (larger diameter than specified by the local/national safety code) is recommended for low electrical resistance at full load during the hottest weather.
- Electrical cables should be sized to minimize energy loss from resistance and not merely satisfy the electrical safety code.
- Stranded wire is preferred because it is more flexible and malleable than solid wire.
- Copper wire is preferred to aluminium wire since copper has lower electrical resistance, stays tight at screw connections, and can handle peak AC electrical loads without generating as much heat.
- Note that some equipment is wired as one phase (two wires) while other equipment is wired as three phase (three or four wires)

Table 1: Specifications of standard wiring components

(Reference: Installation manual)

Component	Specification	
Power supply cable	Voltage	220–240 V
	Phase	1
	Frequency	50 Hz
	Wire size	Must comply with applicable legislation (oversize the wire—use smaller gauge (larger wire) to reduce electric resistance and improve energy efficiency)
IDU-ODU connecting cable	4-core cable ≥ 1.5 mm^2 and applicable for 220–240 V	
Field fuse		16 A
Earth leakage circuit breaker (ground fault interrupter (GFI) or newer, faster acting ground fault circuit interrupter (GFCI))	Must comply with applicable safety legislation	

After selecting electric wires, install the IDU-ODU connecting and power supply cables according to the installation manual.

7. Pipe Insulation

Once the electric wiring work is completed, start insulating the piping as follows:

- **Selecting insulation materials**: Insulation materials should be durable, easy to install, and resistant to water, solvents, chemicals, and UV lights. Be sure to use insulation that is designed for use with HVAC systems. Select insulation materials with thermal conductivity of 0.041 to 0.052 W/m·K and rated Class E (withstanding heat up to 120°C). Typically, polyethylene foam is used. The insulation thickness should be a minimum of 10 mm for tube sizes 6.4 mm to 15.9 mm. However, for hot and humid climate locations (temperature > 30°C and relative humidity (RH) > 80%), the insulation thickness should be a minimum of 20 mm to prevent condensation on the insulation surface. Table 2 provides an example of the suggested minimum insulation dimensions.

- **Insulating pipes**: Separately insulate each pipe (one liquid pipeline and one vapor pipeline) over the entire length.
- **Strapping pipes**: Strap pipes every 3 m to avoid vibration.
- **Finishing tape**: Apply finishing tape or protective split plastic conduit for liquid pipe, gas pipe, and interconnecting cable, as shown in Figure 7, or finishing covers, as shown in Figure 2(b).

Table 2: Pipe insulation material example.

(Reference: Installation manual)

Refrigerant Pipe			Insulation		
Gas line		Liquid line	Gas line		Liquid line
15, 18 class	24 class		15, 18 class	24 class	
OD 12.7 mm	OD 15.9 mm	OD 6.4 mm	ID 14–16 mm	ID 16–20 mm	ID 8–10 mm
Thickness 0.8 mm			Thickness 10 mm minimum		

Note: ID = inner diameter; OD = outer diameter

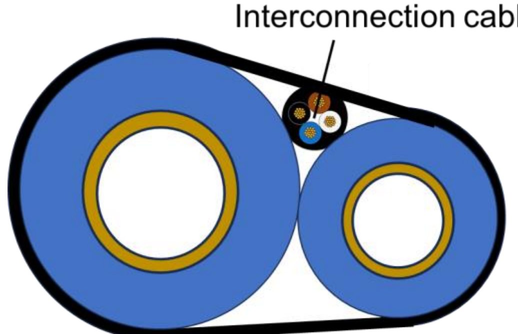

Figure 7: IDU-ODU interconnecting pipes and cable wrapped with finishing tape.

8. Refrigerant Charge Adjustment

The RAC is sensitive to the refrigerant charge, so a best practice is to optimize for energy efficiency. When the charge is lower than the optimum amount, both the cooling capacity and efficiency will be lower than the rated performance. When the charge is higher than the optimum, the cooling capacity becomes slightly higher, but RAC efficiency becomes lower than the rated performance. The ODU is typically factory-charged with refrigerant, but in some cases the following adjustment might be necessary. Only technicians certified with relevant local and national regulations should charge the refrigerant by using the weighing scale.

8.1. Charging with Additional Refrigerant

Before charging with additional refrigerant, be sure of the refrigerant type and charge amount. Table 3 provides an example of a RAC product label showing the type of refrigerant and charge amount. Check the total liquid piping length and compare it with the specified piping length on the installation manual. When the total liquid piping length is longer than specified, additional refrigerant charge will be needed. As an example, if the specified total liquid piping length is 10 m but the actual total liquid piping length is 15 m, then the additional charge is the refrigerant's saturated liquid-state density at the condensing pressure times the additional pipe's internal volume, as shown in Equation (1).

$$M_{addition} = \rho_{liquid} \cdot \pi d_i^2/4 \cdot L_{addition} \qquad \text{Equation (1)}$$

Where $M_{addition}$ is the additional refrigerant change in kilograms [kg], ρ_{liquid} is saturated liquid state density [kg/m^3], d_i is the internal diameter of the liquid line [mm], and $L_{addition}$ is the additional liquid piping length [m].

Table 3: RAC product label showing the type of refrigerant and charge amount.

Rated Power Supply	208/230V, Single Phase, 60 Hz
Cooling Capacity	3,620 W
Power Consumption	822 W
Refrigerant R-32	0.82 kg
Current	3.8 A
Net Weight	32 kg

8.2. Recharging the Full Amount

Important: Before completely recharging refrigerant to the full amount, perform the following actions first:

- Confirm the refrigerant type and charge amount.
- Recover all refrigerant left in the system.
- Verify that the entire system is leakage free and then run the vacuum drying.

Then:

- Charge the system with refrigerant.
- Check the charge ports for leakage and install valve caps at proper torque.

Proper Service for High Energy Efficiency

Equipment owners can help maintain energy efficiency by:

- Keeping indoor and outdoor units free and clear for unobstructed air flow.
- Cleaning air filters and OSU heat exchanger frequently.
- Calling for professional service at the first sign of poor cooling or increased electricity costs.

Conversion of Metric to Imperial Measures

1 meter = 39.37 inches (about 3 feet)
1 centimetre = 0.39 inches
1 millimetre = 0.039 inches (to approximate, divide by 25)

1 kilograms = 2.2046 pounds
1 gram = 0.03527 ounces (16 ounces = 1 pound)

Evacuation to a metric vacuum gauge reading 500 microns is an absolute pressure of approximately 0.02 inch of mercury, which is equivalent to an imperial vacuum reading of 29.90 inches of mercury.

Acronyms and Abbreviations

A	amp, a unit of current
GWP	global warming potential (carbon dioxide is the reference with GWP=1)
Hz	Hertz, a unit of frequency
IDU	the indoor unit of a room air conditioner
K	Kelvin, a unit of temperature
kg	kilogram
kPa	kilopascal
LCCP	life cycle climate performance
m	meter
m^3	cubic meter
mm	millimetre
ODU	the outdoor unit of a room air conditioner
PPE	personal protective equipment
RAC	room air conditioner
W	Watt
d_i	internal diameter of the liquid line [m]
$L_{addition}$	additional liquid piping length [m]
$M_{addition}$	additional refrigerant change [kg]
ρ_{liquid}	saturated liquid state density [kg/m^3]
P_1	initial pressure [kPa]
P_2	final pressure [kPa]
T_1	initial temperature [K]
T_2	final temperature [K]

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